Development of Forced Pulse Water Strip of Tungsten Carbide HVOF Coatings and Chrome Plating on Aircraft, Landing Gear and Propeller Components

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**SERDP/ESTCP Workshop –
Surface Finishing and Repair Issues
for Sustaining New Military Aircraft**

Fiesta Resort and Conference Center, Tempe, AZ

Feb 26-28, 2008

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Agenda & Project Overview

- Agenda & Project Overview
- Objective
- Benefits
- Status
- VLN - FPWJ Theory
- Phase I Test Results
- Messier-Dowty Test Results
- Contact Information
- Questions

USAF SBIR Phase I Awarded to ES3

USAF SBIR Number F071-317-0028
Period Of Performance: 5Jul07 to 3Apr08

Joint SBIR between Hill & Robins AFB

Craig Shaw, Hill AFB
Greg Sutton, Robins AFB

USAF Tech Leads

Ryan Josephson, Hill AFB
Richard Newton/John Jacobs, Robins AFB

ES3 teamed with VLN Advanced Technologies

Commercialization Interest:

Messier-Dowty, Boeing, Heroux-Devtek, Goodrich, KLM, Delta Air Lines, Tinker AFB, FRC-East/ISSC @ Cherry Pt., FRC-Southeast @ Jacksonville, and others

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Objective

The objective of the Phase I Feasibility study was to develop the parameters that could strip both hard chrome plating and HVOF tungsten carbide coatings consistently and repeatedly, without visually or dimensionally damaging the substrate.

Hill AFB: Focus is Landing Gear
- 300M High Strength Steel substrates
- HVOF coating is WC-Co

Robins AFB: Focus is Aircraft and Propeller
- 4340 Low Strength Steel substrates
- HVOF coating is WC-Co-Cr

Phase II – Qualification Testing

Phase III – Commercialization and Technology Insertion

Benefits

A process that will strip both chrome plating and HVOF tungsten carbide coatings from high & low strength steel alloys

Elimination of multiple wet chemical strip tanks

Elimination of hydrogen embrittlement issues that are associated with the wet chemical strip process

Elimination of embrittlement relief bakes

Reduced process time

Environmentally friendly process

Utilization of basic water (no abrasives) in a recycled system

Project Status

Phase I Feasibility testing successfully completed and report submitted to the USAF.

Phase II is being initiated and scheduled to start at conclusion of Phase I PoP, Apr08.

Other DoD Repair Depots contacted and invited to join Phase II testing.

- **Incorporate specific depot or weapon system test requirements with same plating/coatings and substrate combinations.**
- **Add test programs for other finishes and / or substrate combinations.**

OEM's being contacted or in discussions for complimentary test programs.

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VLN – FPWJ Theory

FORMATION OF FORCED PULSED WATERJET

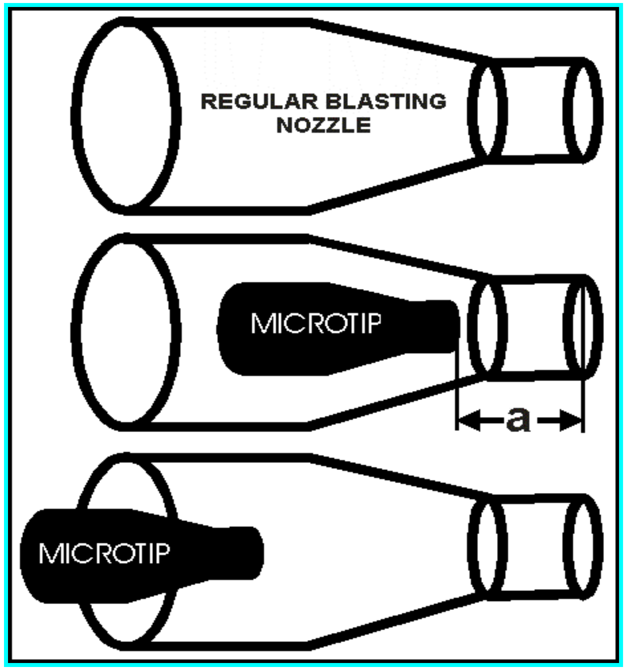
↓

HIGH-FREQUENCY PULSES OF WATER ARE GENERATED BY MODULTAITNG A CONTINUOUS STREAM OF WATER

↓

AS SHOWN IN THE NEXT SLIDE, MODULATION IS ACHIVED BY INDUCING ULTRASONIC WAVES USING A MICROTIP IN THE NOZZLE

VLN – FPWJ Theory



VLN – FPWJ Theory

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FULLY DEVELOPED HIGHLY EFFICIENT PULSED WATERJET IS PRODUCED WHEN

'a' VALUE IS OPTIMUM FOR GIVEN VALUES OF

PRESSURE
FLOW
AND
ULTRASONIC POWER INPUT

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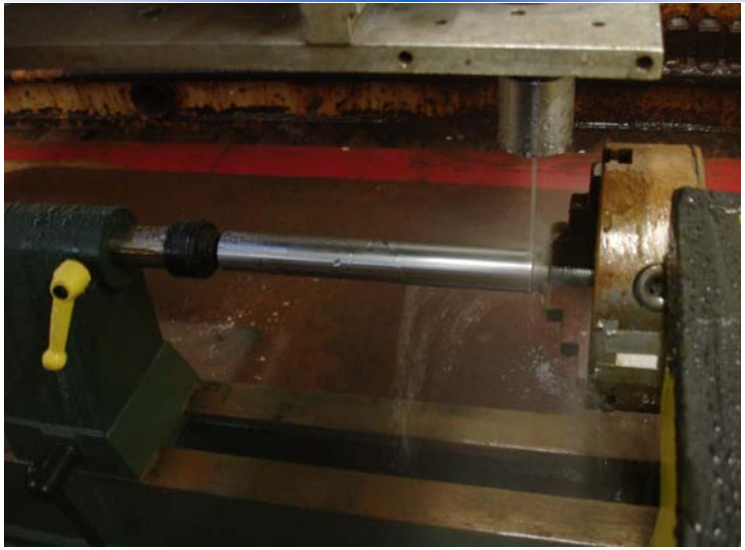
Phase I Test Results



Left: View of Chrome plated, HSS coupon prior to pulse waterstrip.

Right: View of the coupon after complete chrome plating removal by pulse waterstrip.

View typical for LSS. Process time was approximately 60 seconds to remove 0.005 inch thick chrome plating along the length of a 1 inch diameter, eight inch long coupon. There is no visual or dimensional damage to the HSS substrate.

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Phase I Test Results

Left: View of HVOF WC-Co-Cr coated, LSS coupon prior to pulse waterstrip.

Right: View of the coupon after complete coating removal by pulse waterstrip.

View typical for HSS with HVOF WC-Co coating. Process time was approximately 120 seconds to remove 0.005 inch thick HVOF coating along the length of a 1 inch diameter, eight inch long coupon. There is no visual or dimensional damage to the LSS substrate.

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- Agenda & Project Overview
- Objective
- Benefits
- Project Status
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Surfaces were visually inspected under 25X magnification to observe surface texture characteristics.

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Phase I Test Results

4340 - Stripped Chrome Plated Coupons

Serial Number	Pre-Coating Diameter (in)	Post-Strip Diameter (in)	Weight Loss/Gain (%)	Post-Strip Surface Finish (µin)
ES3-004	0.9937	0.9940	-0.015	87.3
ES3-005	0.9936	0.9940	-0.009	85.2
ES3-006	0.9936	0.9940	0	88.5

4340 - Stripped HVOF Coated Coupons

Serial Number	Pre-Coating Diameter (in)	Post-Strip Diameter (in)	Weight Loss/Gain (%)	Post-Strip Surface Finish (µin)
ES3-011	0.9935	0.9946	0	121.1
ES3-012	0.9935	0.9946	-0.004	120.6
ES3-013	0.9935	0.9947	+0.006	129.8

Phase I Test Results

300M - Stripped Chrome Plated Coupons

Serial Number	Pre-Coating Diameter (in)	Post-Strip Diameter (in)	Weight Loss/Gain (%)	Post-Strip Surface Finish (µin)
ES3-002	0.9937	0.9940	0.235	40.7
ES3-005	0.9937	0.9940	0.164	39.6
ES3-008	0.9937	0.9940	0.201	44.6

300M - Stripped HVOF Coated Coupons

Serial Number	Pre-Coating Diameter (in)	Post-Strip Diameter (in)	Weight Loss/Gain (%)	Post-Strip Surface Finish (µin)
ES3-010	0.9935	0.9941	-0.077	109.2
ES3-011	0.9935	0.9943	-0.064	94.7
ES3-012	0.9935	0.9943	-0.083	111.7

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Messier-Dowty Test Results

Agenda & Project Overview

Objective

Benefits

Project Status

VLN - FPWJ Theory

Phase I Test Results

Messier-Dowty Test Results

Contact Information

Questions

Water Jet Stripping of HVOF Coating

Messier-Dowty Test Results

Background

Messier-Dowty SAFRAN Group

- Messier-Dowty (M-D) worked with VLN Advanced Technologies Inc. to optimize their forced-pulse waterjet (FPWJ) process to strip a landing gear part HVOF coated with WC-Co-Cr.

- All coatings stripped were in the as-sprayed condition. No tests were performed after the HVOF coating was super-finished.

- M-D performed a number of studies with VLN to:
  1. Assess VLN ability to strip HVOF coated parts.
  2. Strip HVOF coated parts without any visual or dimensional damage to the metal substrate.
  3. Determine the resultant surface residual stresses after stripping using x-ray diffraction (XRD).

Messier-Dowty Test Results

Experimental Part

Messier-Dowty
SAFRAN Group

- Landing Gear Pin
- 300M steel (HRc 53-55)
- HVOF coated with WC-Co-Cr
- Coating thickness = approx. 0.015”
- Length = 10”
- Diameter: Tapered

Messier-Dowty Test Results

XRD Measurement

Messier-Dowty SAFRAN Group

- One pin stripped using VLN waterjet process was examined to determine the resultant surface residual stresses after stripping.
- The intention was to determine if the resulting cyclic loading of the water pulses negate the compressive stresses induced in the pin during the shot peen operation.
- Shot peening induces compressive stresses which allows a component to carry higher cyclic stresses,thus, improving its fatigue performance.
- Any operation that decreases the shot peen effects would be considered un-acceptable.

Messier-Dowty Test Results

XRD Measurement – cont'd

Messier-Dowty SAFRAN Group

- Agenda & Project Overview
- Objective
- Benefits
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- Phase I Test Results
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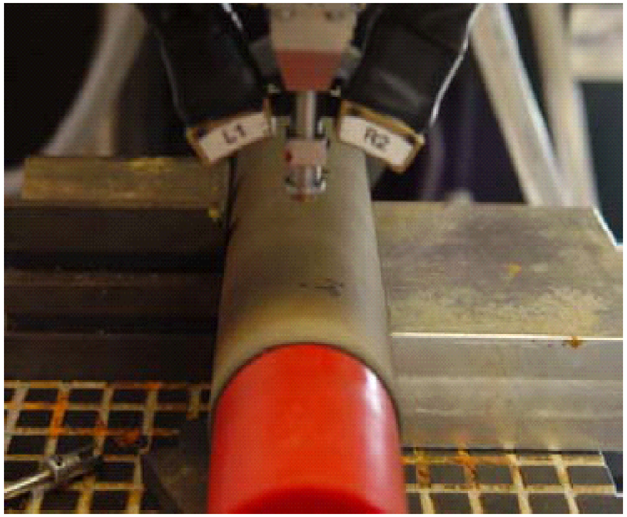
- Six(6) measurements were taken on one of the stripped pins, three(3) each in both the longitudinal and transverse grain directions of the pin.
- All measurements were compressive (-ve), ranging from –59ksi to –71ksi.
- This indicates that the cyclic loading of the waterjet pulses on the coatings did not affect the material surface stresses.

Experimental Results : Surface Residual Stress

Location: (see photograph below)

Location:	Longitudinal Stress (ksi)	Transverse Stress (ksi)
Top	-68 ± 1	-67 ± 1
Middle	-59 ± 2	-64 ± 1
Bottom	-64 ± 1	-71 ± 1

Measurement Locations & Picture:



VLN Advanced Technologies Inc.

Engineering & Software System Solutions Inc

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Agenda & Project Overview

Objective

Benefits

Project Status

VLN - FPWJ Theory

Phase I Test Results

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Questions?